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ABSTRACT

The Print and Computer Enlargement (PACE) System is being designed as a portable computerized reading and writing system that enables a low-vision person to read regular print and then create and edit text using large-print computerized output. The design goal was to develop a system that: weighed no more than 12 pounds so it could be easily carried by students from class to class; would be operable for over 8 hours on internal rechargeable batteries; and would sell for under $3,500. The system design utilizes a hand-held optical scanner, a portable laptop personal computer running the MS-DOS operating system, a "screen catcher" circuit board, and software to generate large print. PACE would produce large print for any printed material scanned by the optical scanner and for any application program that runs on the operating system. Efforts in creating PACE involved the following objectives: select laptop computers; locate hand-held optical scanner; design and test screen catcher circuit board; create optical scanner large-print software; create large-print characters from computer; create the user interface module; field test PACE; and create a national marketing plan for PACE. The project was partially successful, in that it developed and implemented all PACE functions on a MS-DOS compatible desk top computer, but was unable to implement the design on a portable laptop computer. (JDD)

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FINAL REPORT

THE PRINT AND COMPUTER ENLARGEMENT SYSTEM -- PACE

U. S. DEPARTMENT OF EDUCATION
GRANT NO. G008730316

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INTRODUCTION

Automated Functions, Inc. is pleased to submit this final research report describing our work on The Print and Computer Enlargement System -- PACE funded by the United States Department of Education Grant No. G008730316.

Automated Functions, Inc. (AFI) is a small company engaged in the development of aids for the blind and visually impaired. The President of AFI is blind and is a recognized leader in the field of computer generated speech. AFI created the popular VERT speech systems which are distributed world wide by Telesensory Systems, Inc. We have also created a talking laptop computer.

AFI has a good understanding of the needs of visually impaired people. We recognized that low vision students and workers did not have a portable reading and writing system. We studied literature on commercially available laptop portable computers and believed it was possible to create a portable reading and writing system for low vision users.

ABSTRACT

The Print And Computer Enlargement (PACE) system was designed to be a portable computerized reading and writing system that enables a low vision person to read regular print and create and edit text using large print computerized output. The design goal was to develop a system that weighed no more than 12 pounds so it could be easily carried from class to class. It should run for over 8 hours on internal rechargeable batteries. The target price including the computer is under $3,500. This price will only be possible if extensive use of commercially available products is made.

The system design utilizes a hand held optical scanner, a portable lap top personal computer running the MS-DOS operating system, a "screen catcher" circuit board, and software to generate the large print. The optical scanner is used to read any printed material, which in turn is displayed in large print on the computer display. Anything typed on the computer keyboard or displayed by the application program (e.g., Wordperfect), is shown in large print.

PACE enables the low vision user to optically scan any printed material. Any application program that runs on the MS DOS operating system is also enlarged. The user can quickly and easily change the size of the letters for individual preferences.

DISCUSSION

The following describes our effort in creating PACE. It includes a detailed description of the research problem and the methodological approach used in our study. Each objective that was presented in our original proposal is listed separately with a discussion of the problem, the approach, and the results. A summary discussion and conclusions follows this section.

OBJECTIVE 1. -- Select Lap Top Computers.

The first objective for PACE was to select an off-the-shelf portable computer. AFI created a list of mandatory and desirable functions needed in the computer. The mandatory requirements were ones that absolutely must be present. The desirable requirements were ones which added value but were not absolutely necessary. The mandatory and desirable requirements are listed below.

MANDATORY REQUIREMENTS FOR PACE LAPTOP COMPUTER

* Weight under 15 pounds.
* Large bright screen.
* Battery powered -- at least 5 hours.
* Access to complete PC bus.
* Modem slot.
* MS-DOS operating system.
* Color graphics adapter interface.
* Attachment for regular color monitor.

DESIRABLE REQUIREMENTS FOR PACE LAPTOP COMPUTER

* Hard disk option.
* removable battery pack.
* Automobile power converter.

AFI surveyed the laptop computer market and compared vendor specifications to the mandatory requirements. The two mandatory requirements that were difficult to find in a laptop computer were the large bright screen and the access to the PC bus. The large bright screen is subjective, since it is not clear how bright or large is large enough.

Five laptop computers, the Toshiba 1200, NEC Multi-speed, Zenith Super Sport, Sharp portable, and the IBM Convertible were selected for evaluation based on the survey criteria. We were able to evaluate these machines without purchasing them due to cooperation from local computer distributors in the Washington,

D.C. area. AFI wrote a test program that created large text on the computer screen. We then asked a variety of low vision people to compare the large print displayed on the different laptop computer screens.

The only screen the low vision people judged adequate was the Zenith Super Sport. In fact this was the only screen that presented characters that most of them could see. The Zenith computer has the largest screen of any laptop. For example, the Toshiba 1200 screen is hinged in the middle of the computer. In contrast, the Zenith screen is hinged at the rear of their computer. Therefore, the Zenith screen occupies the entire lid of the computer, whereas the Toshiba screen occupies half their lid. The Zenith screen also has the back lit feature which adds more brightness to the display.

We also looked at plasma displays. The screens were bright, but the battery life is short. The cost of the plasma screens were also very high. For example, the list price of the Zenith 184 Super Sport was $2,300 whereas the Toshiba 5100 plasma computer was $5,600.

The next mandatory requirement which had to be met was complete access to the computer's bus. The bus in a computer transfers information from the central processing unit (CPU) to memory or to any peripheral. The complete bus was needed for the hand held optical scanner and the Screen Catcher Circuit Board. We contacted our local Zenith representative and were told that the Zenith laptop computers had a complete bus.

The only laptop computer which met the mandatory requirements was the Zenith Super Sport. It comes with two 720K floppy disk drives or one 20 megabyte hard disk and onel 720K floppy drive.

AFI purchased a Zenith 184 Super Sport with two 720K floppy drives. This model was less expensive than the hard disk system. AFI performed all software development on a regular IBM PC with a hard disk, so the Zenith was only used for testing.

RESULTS:

OBJECTIVE 1 was successfully completed with the selection of the Zenith Super Sport laptop computer.

OBJECTIVE 2 -- LOCATE HAND HELD OPTICAL SCANNER.

A vital part of PACE is the ability for the user to read regular

printed material. The user could take the laptop computer to any location, select printed material, and then use the hand held optical scanner to read the material. The user would move the scanner along the printed text and then see the enlarged image on the laptop display.

AFI surveyed technical periodicals for commercially available hand held optical scanners. The only ones available were designed for desk top publishing. They were 2 1/2 inches wide and scanned from the top of the page to the bottom. Their design was intended to read one column of a magazine or a picture. The width of 2 1/2 inches was too small for large print use. The user would have to make three or four passes over an 8.5 by 11 inch sheet of paper.

AFI found that Kurzweil Computer Products had just announced a reading machine with a hand held scanner as an option. We received a demonstration of the device and the hand held scanner. The Kurzweil scanner was perfect for PACE. It was small and attached to the computer. We contacted the design engineer at Kurzweil Computer Products and discussed the technical aspects of their scanner. Technically this scanner met our requirements.

We then talked to Kurzweil Computer Products management about obtaining information and prices for the scanner. They would not furnish us with any technical information. They were only interested in working with us if they performed all of the work. In addition, they estimated it would cost about $100,000 to adapt their scanner for our purpose. We rejected their offer and continued our search.

We contacted a local firm in Alexandria, Va. which makes scanners for reading maps. The firm indicated it would cost about $150,000 to have a scanner designed and tested. This did not include the cost of producing the scanners.

We continued our survey of the technical periodicals and found that Logitech Inc. just announced a four inch hand held scanner. The price for their scanner was $295. Its purpose was for desk top publishing, but this larger size was much more attractive. The user would only need to make two passes over a document to read the entire page. We contacted Logitech Inc. and found that they would not release any technical information. They would provide samples of software, but no hardware information. It would be nearly impossible to interface a scanner to the laptop computer without a schematic.

At this point we were very frustrated with our progress in locating a commercially available scanner that would meet our

needs. Then we did locate two scanners that met our performance criteria but these companies would not release technical details that we required to interface the scanners to the laptop computer. We stressed to both companies that our use of the scanners was to aid low vision people. We also stressed that we were willing to sign a non-disclosure statement saying this would be the only use we would apply with their scanners. In both cases the answer was no.

We continued our search by looking through the technical periodicals and talking with people in the field of optical scanning. We got a lead that a company was creating a four inch scanner to compete with the Logitech scanner. We contacted the Complete PC and talked to their management. We explained what we needed and our experience with Kurzweil and Logitech. They were very interested in our project and sent us an early beta test model of their four inch scanner. More importantly, they furnished us both software and hardware technical information.

We tested the Complete PC hand held four inch scanner on a regular PC. The scanner worked well and the list price was $295.

RESULTS:

OBJECTIVE 2 was successfully completed.

We found three hand held optical scanners that met our needs. We found only one company, Complete PC, that was willing to share technical information. We thank the Complete PC for their openness and willingness to work with us on this project.

OBJECTIVE 3 -- DESIGN AND TEST SCREEN CATCHER CIRCUIT BOARD.

The PACE system design is based on the Zenith laptop computer and a Complete PC hand held scanner. The Zenith laptop computer runs the MS-DOS operating system. It includes a 25 line by 80 column back lit LCD super twist display.

When characters are typed on the keyboard they are sent to the memory of the display. The display in the Zenith computer emulates a color graphics adapter (CGA). The screen can only display black and white and shades of gray. The software that runs on the computer thinks it is writing to a regular color screen. In fact, if a color screen is attached to the Zenith laptop regular colored text appears on the color monitor.

A Screen Catcher Circuit Board (SCCB) is also required in the

PACE system design. This module is needed to perform two tasks. First it captures any data intended for the color graphics memory. It would then place this data in an internal memory. The PACE large print software would look at this auxiliary memory and draw the enlarged text on the color graphics screen. The second task for the SCCB is to interface to the optical scanner. Both the tasks required by the SCCB depend on interfacing to the computer's bus.

AFI engineers designed a more efficient way to capture the data intended for the display. They designed an interface to the computer that looked like a monochrome screen. The software would tell MS-DOS that the computer had a monochrome screen. The monochrome screen has a different memory space than the color screen. The application program (e.g., WordPerfect) would write its data to the monochrome screen memory. The PACE large print software would take the data from the monochrome memory and draw the characters on the regular color screen. In this way, the monochrome memory was serving as a holding area.

The above architecture is more efficient than taking data directly from the bus. Their are no conflicts with application programs changing registers on the CGA adapter.

AFI developed and tested this concept on a desk top PC. We were able to implement a working system on a desk top computer by using commercially available modules designed for monochrome and color displays. A color monitor was attached to a CGA adapter board. AFI wrote software to inform MS-DOS that it was using a monochrome screen. All application programs then wrote their information to the monochrome memory. The color display was free to accept the graphic large print characters.

The Complete PC scanner was interfaced to the desk top PC based on information furnished by the manufacturer. Tests were run to assure that the interface worked. At this point the entire PACE system design was successfully implemented on the desk top computer.

The next and critical task was to make the SCCB design work with the Zenith laptop computer. Although the logic design is the same for the desk top and the laptop computer, the form factor is substantially different. Desk top computers use a mother board for some of the major components of the computer. Internal expansion slots are used for additional components like the display interfaces and the scanner interface. These expansion slots conform to a de-facto IBM PC bus standard and are well documented. Laptop computers, on the other hand, must design within severe power and space constraints because they must remain small and consume little power to be portable. The power,

control, and data signals are present but may be organized and distributed in non-standard ways.

AFI obtained technical information on the Zenith 184 Super Sport laptop from Zenith Corporation. Our design required two essential elements in the laptop. First, we needed an adequate power source, including +5 volts for the logic circuits and 12 volts to drive the hand held optical scanner. Second, we required a complete, PC compatible, bus structure to interface both the scanner and the monochrome memory to the laptop CPU. Our early evaluation of this unit had indicated that both of these elements were present in the Zenith design.

We studied the technical information. We found a place to take the plus 12 volts. We tested this and the voltage was there.

We began this phase of the development by designing a simple interface to test the Zenith bus. We wanted to try something easy before proceeding with the interface for the optical scanner. We were unable to read or write data over the the Zenith bus. For several weeks we assumed that our simple design was in error. We also requested additional technical information from Zenith on their bus. They refused to furnish us detailed information on their bus, stating they were applying for a patent.

We discovered Zenith was planning to release an external bus unit. This unit would plug into the Zenith laptop and accept regular sized PC boards. It would not be portable, but must interface to their bus. We purchased one of the first external bus units available from Zenith and were also able to purchase the technical maintenance manual. We planned to determine the characteristics of the Zenith internal bus by monitoring the signals sent to the external bus. We also expected that information in the technical maintenance manual would provide details needed to proceed with our design.

We were able to make the scanner work when connected to the Zenith external bus. This proved that the scanner could be interfaced to the Zenith laptop. Now we had to determine how but without benefit of documentation.

We connected the external bus unit to the Zenith laptop and used a logic analyzer to look at the signals going over the bus. We discovered parts of the bus were active at different times. When the Zenith laptop is powered on, a program is downloaded to the external expansion box. This program is then used to communicate with the main logic in the laptop. We requested information from Zenith regarding the sequences needed to read and write data over this bus. Zenith was unwilling to provide this information

despite repeated requests. Unfortunately, this made it impossible for us to determine the hardware logic or the software to use the scanner with the Zenith laptop.

RESULTS:

OBJECTIVE 3 of PACE was only partially completed.

The Screen Catcher Circuit Board design was implemented successfully on a desk top PC. We were unable to make this critical element work with the Zenith laptop computer. We still believe that this is possible but we have been unable to gain access to sufficient technical information regarding the Zenith bus.

AFI is very interested in PACE. We believe the system will help a great deal of low vision students and professionals. We are continuing, at our own expense, to try and finish the project. We continue to contact Zenith Corporation trying to get information on their bus. Recently Toshiba announced a new laptop computer with a screen 80% the size of the Zenith. We are requesting technical information on their computer. For now, however, this part of the development is unfinished.

OBJECTIVE 4 -- CREATE OPTICAL SCANNER LARGE PRINT SOFTWARE.

The PACE system design includes a laptop computer attached to a hand held optical scanner. The low vision user may use the scanner to read any book or periodical.

AFI received a Complete PC four inch hand held optical scanner that attached to a desk top PC. The vendor provided us with a sample device driver. This software demonstrated how to accept data from their scanner. We experimented with the scanner and determined the best user format.

The user places the scanner on the top left side of the paper. The user then pulls the scanner down the page. As the scanner is rolling down the page, the image of the text is displayed on the computer screen. This visual feedback aids the user in rolling the scanner straight. The scanner has a long roller which makes it pull naturally in a straight line. The edge of the paper or book can also be used as a guide. When the user is scanning the text it is also being saved on disk. In this way, the user may quickly review the scanned data without using the scanner. The time needed to scan a complete 8.5 by 11 inch sheet of paper (2 passes) was only about 12 seconds.

The AFI software team divided this task into two projects. The first project was the low level device driver program. This program interfaced to the scanner and furnished the scanned text to the print system. The other project was the print system. It accepted data from the low level device driver printed it to the display and stored a copy on disk. It also let the user browse the disk file, change colors, and magnify the image. The print system also enabled the user to rotate the scanned image. This is necessary if the user pulls the scanner across the page. This is sometimes necessary if the scanner cannot physically fit into an edge of a book. The two software projects are described below.

LOW LEVEL DEVICE DRIVER

The Complete PC furnished AFI with a prototype device driver. The program demonstrated the input/output sequences needed to accept data from the scanner.

The low level device driver must work from a PC interrupt. AFI used interrupt 2, since this one is unused in the Zenith laptop. The program was written in IBM PC Assembly Language. The device driver was written to share memory space with the print program. In this way, the print program could quickly gain access to the scanned text.

The Complete PC scanner uses Direct Memory Access (DMA) to write its data. The device driver furnishes the beginning address and the scanner transfers one line of data to that address. The scanner then generates an interrupt and the device driver gains control again. It calculates a new address and outputs it to the scanner.

It was crucial that the AFI device driver be written efficiently. When the device driver has control of the CPU, the scanner cannot transfer any information. This is why AFI wrote the low level device driver in Assembly Language. It is programmed very efficiently and does not slow down the scanner.

PRINT SYSTEM

The print system was written in the C Language. It was written to interface with the low level device driver and communicate with the user.

The print system software permits the user to save the scanned text on any disk file. The image may be rotated, magnified, or displayed in different colors. The system uses menus to communicate with the user. In this way, the user simply selects the desired option from the menu. The system also includes help,

if the user is not clear on how to proceed. An internal AFI write-up (intended for testers) follow. It will provide a feel for the user interface to the print system.

THE SCANNER

The scanner is a brick shaped device with the cord in the back and a four inch scanning window on the bottom in the front. The indented line across the length of the scanner shows where it will begin to read text. The two indented lines on the front of the scanner show the width of the area to be scanned.

When you turn the scanner over, you can see the scanner's window, and the rollers. You can scan text horizontally or Vertically, but the rollers must be free to move. No matter which direction you go, the wide part of the scanner must be pointing in that direction.

The scanner has three controls. The button on the top starts and pauses the image processing. When the red scanner light comes on, the button must be pushed before the scanner records any images. If you wish to skip a section or to move the scanner during the middle of a scan, simply push the button to stop the scanner from recording images, move it, and push the button again to restart. The button will not end the scan; a key on the keyboard must be pressed to turn off the scanner light and bring the entire file to the screen.

On the back of the scanner on the left side, there is a brightness dial. To make lighter images turn the dial towards the outside edge of the scanner. To make darker images, turn the dial towards the middle of the scanner.

Next to the brightness dial, is a contrast switch. It has four settings, with setting four closest to the brightness dial. Setting one is best for items that are just black and white. Settings two through four allow greater shades of gray and other colors. Since the scanner uses a red light, it can not read red print.

THE MAIN MENU

From the large print program, type SCAN. The main menu appears.

Main Menu

A> Use Scanner.
B> Read a File.
C> Quit.

To use the scanner, type "A","U", or "S". You are asked to enter the name of a file in which to put the scanned data. If that filename already exists in your directory, it asks if you want to overwrite that file. Type "Y" to erase the old file. If you type "N", a new filename is requested.

After a file has been opened for your data, the red scanner light comes on. Push the button on the top and pull the scanner at an even pace down the page. When you are finished, press any key on the keyboard to turn the scanner off.

To read a file previously created with the scanner, type "B" or "R". You are asked for the name of a file. If the file is not in your directory, you are asked to enter another filename. When the file you want to read is found, the first section will appear on the screen. If you decide you do not want to read a file, press the "ENTER" key when a filename is requested, and you will go back to the main menu.

To quit type "C" or "Q" or press the "Escape" key. You will be returned to the large print program at DOS level.

Rotating

If the text you scanned appears on the screen upside down, sideways or backwards, it can be rotated or flipped. Type "R" to bring up the rotation menu.

ROTATION MENU

Select Angle of Rotation

A> 90 degrees
B> 180 degrees
C> 270 degrees
D> Flip
E> Quit

When a file is rotated 90 degrees, it moves counterclockwise. What was at the top of screen appears at the left side of the screen. A 180 degree rotation turns the file upside down, making the top the bottom and the bottom the top. A 270 degree rotation moves the file clockwise, it turns the file so what was on the top is now on the right side. Flipping the file gives you the mirror image of what was there before. It takes what was on the left side and puts it on the right and vise versa. You may exit and return to the main menu by typing "E" or "Q" or pressing the escape key.

Magnify

If the text on the screen is too small, it can be enlarged by typing "M". You can move around the screen as you would before, and the text remains magnified. To reduce the text to its original size, type "U" (Unmagnify).

Colors

The scanned text appears in black and another color of your choice. When the program begins, the other color is the same as the background color in the large print program. If the background color is black, it is changed to blue. The colors are:

0	Black
1	Blue
2	Green
3	Cyan
4	Red
5	Magenta
6	Brown/Yellow
7	Light Gray
8	Dark Gray
9	Light Blue
10	Light Green
11	Light Cyan
12	Light Red
13	Light Magenta
14	Light Yellow
15	White

To change the color, you may either step through the colors one at a time or type the color number. To go up by one color, type ">". To go back a color type "<". To enter a color"s number type the number then "C". For example, "10c" would change your screen to light green and black. To inverse the colors, type "I". If your text is red on black, it changed to black on red.

Moving Around the Screen

Control Home	Top Left
Control End	Bottom
Control Right Arrow	Move right one screen
Control Left Arrow	Move left one screen
Page Up	Move up one screen
Page Down	Move down one screen
Home	Left Margin
End	Right Margin
Right Arrow	Move Right
Left Arrow	Move Left

Up Arrow	Move Up
Down Arrow	Move Down
Q, escape	Quit

Review of Commands

H	Help
R	Rotate
M	Magnify
U	Unmagnify
I	Inverse colors
>	Forward one color
<	Back one color

RESULTS:

OBJECTIVE 4 was successfully completed.

AFI wrote software to capture data from the optical scanner and display it on the screen. The image was saved to disk so it could be reviewed at a later time. The software provided a friendly menu system which allowed the user to view the captured scanned text in many different formats.

OBJECTIVE 5 -- CREATE LARGE PRINT CHARACTERS FROM COMPUTER.

The PACE system allows the user to scan text via the optical scanner and view the image on the Zenith laptop screen. The scanned text is saved on disk and may be viewed in different colors and magnification. PACE also enables the low vision user to operate the computer and receive large print.

The low vision user cannot see the regular size print on the display. The user needs to perform functions such as word processing, data management, spread sheet analysis and more. Any application program that runs on MS-DOS must be able to be enlarged.

AFI designed an architecture for the large print program. It utilized the monochrome memory as a holding area for the color graphics screen. The program was structured to be resident in memory. This permits it to be active while other programs (e.g., WordPerfect) are running.

First, AFI software engineers created six different sizes of characters. Each of the 256 characters of the ASCII set were used. The large print program was written and tested on a desk top PC. It was tested with the Screen Catcher Circuit Board on

the desk top computer. The program ran well and displayed the large print on the screen.

The commands used in the large print program follow:

LARGE PRINT COMMANDS

Control M	Enter Review Mode.
Escape	Exit Review Mode.
Left Cursor	Left one column.
Right cursor	Right one column.
Up Cursor	Up one line.
Down cursor	Down one line.
Home	Upper left corner.
Page up	Upper right corner.
Page down	Lower right corner.
End	Lower left corner.
Tab	Forward one word.
Shift tab	Back one word.
S	Change size of characters.
L	Display location of cursor.
M	Show map of entire screen.

Colors:

F1	Normal text color.
F2	Background color.
F3	Bold text color.
F4	Blinking text color.
F5	Lower case presentation.
F6	Underscore text color.
F7	Cursor character color.
F8	Color used for underscore symbol.
F9	Color used for cursor symbol.
F10	Restore default parameters.

The user could at any time change the size of the characters. Only a portion of the entire screen could be displayed on using large print. The user could easily move the large print window around to read the entire screen.

When the user was running an application program such as WordPerfect the large print display would move along with the cursor. In this way, the low vision user could see the area near the cursor.

The user could enter Review Mode and then read text not displayed on the screen. Pressing "M" would display a map of the entire screen. The area that was being viewed in large print would be

represented in a different color. This permitted the low vision user to quickly gain a feeling of where the large print viewing area was located relative to the entire screen. Pressing any key would return to the large print presentation.

The user could also run the "Scan" program from the large print program. When this occurred the messages and menus appeared in the color selected by the low vision user. When the scanning and reading of the text was complete the user could exit back to MS-DOS. Again, the large print program would enlarge the characters.

RESULTS:

OBJECTIVE 5 was successfully completed.

AFI created a large print program that ran with any MS-DOS program. It also interfaced completely with the scanner program. The user could operate all programs via large print and also read data scanned from the hand held optical scanner. All programs ran on a desk top IBM PC compatible computer.

OBJECTIVE 6 -- CREATE THE USER INTERFACE MODULE.

The User Interface Module is the part of PACE that communicates directly with the user. This module was included in the large print program that was written for OBJECTIVE 5.

The User Interface Module was integrated into the large print program to save memory space. Having just one program to run, makes it easier for the user. The User Interface Module provided a friendly easy to use interface to PACE. More detailed information can be found in the previous objective.

RESULTS:

OBJECTIVE 6 was successfully completed.

The User Interface Module was part of the large print program. It was structured to be easy to use. Incorporating it into the large print program eliminated one more program the user would have to remember.

OBJECTIVE 7 -- FIELD TEST PACE.

AFI proposed to field test the PACE system in cooperation with the Prince George's County School District in Maryland. Ten low vision students would serve as field testers. Questionnaires to measure how well the students could use PACE were to be developed by AFI and the PG County teachers. The design would then be modified based on this feedback.

The PACE system was designed, developed and completely implemented on a MS-DOS compatible desk top computer. The system did not run on the target Zenith laptop computer because of reasons listed in OBJECTIVE 3 above. The Screen Catcher Circuit Board design could not be transferred to the Zenith laptop without adequate technical information.

Even though the PACE system operates successfully on a desk top PC we did not perform the proposed field tests since we were unable to transfer the PACE design to the laptop computer. Performing the field test on a desk top computer would not accomplish our basic objective of demonstrating the utility of a portable reading device for low vision students and professionals. We needed to know how the low vision students could use the equipment in school. The students needed to carry the computer from class to class. They needed to take it to the library and scan books and magazines. They also needed to take it home in order to do homework or perform leisurely reading. The PACE system implemented on a desk top computer is useful to low vision users but it does not meet the objectives stated above.

RESULTS:

OBJECTIVE 7 was not attempted.

AFI decided that it was not a good use of grant funds to perform a field test of PACE with a desk top computer instead of a portable laptop. We felt that this type of limited test would not satisfy the objectives stated above. AFI did not request funds for OBJECTIVE 7 as originally proposed and did not use the funds for other purposes.

AFI believes it will either locate another laptop computer that has a documented internal bus, or gain access to Zenith Corporation information on their bus. We strongly believe PACE will help many low vision students and low vision people. AFI has invested many hundreds of hours performing hardware and software tasks for PACE. We appreciate the support shown by the Department of Education by giving us the opportunity to create such a worthwhile device. We plan, at our own expense, to

continue this research.

OBJECTIVE 8 -- CREATE A NATIONAL MARKETING PLAN FOR PACE

RESULTS:

OBJECTIVE 8 was not performed because the development of the PACE system is incomplete. AFI did not request funds for this objective.

SUMMARY OF RESULTS AND CONCLUSIONS

The goal of the PACE project was to develop a portable reading and writing system that would enable a low vision person to use a laptop computer via large print output. It would also permit the user to read, at any location, via a hand held optical scanner any printed information. The PACE design permits the low vision user full access to a laptop portable MS-DOS computer by presenting all application programs in large print.

AFI successfully developed and implemented all PACE functions on a MS-DOS compatible desk top computer. We were unable, however, to implement our design on a portable laptop computer. Therefore, this development project was only partially successful.

AFI decided that it was not a good use of grant funds to perform a field test of PACE with a desk top computer instead of a portable laptop. We felt that this type of limited test would not satisfy the objectives of this project.

We were able to locate a suitable hand held optical scanner available for under $300 from The Complete PC. This scanner was interfaced to the desk top computer and was used to successfully read text from any printed material. AFI wrote a large print program that displayed scanned text as well as computer generated text in large print.

Five laptop computers, the Toshiba 1200, NEC Multi-speed, Zenith Super Sport, Sharp portable, and the IBM Convertible were evaluated based on PACE requirements. From this group the Zenith 184 Super Sport laptop computer was selected as the target system for PACE. It was chosen because it was the only laptop computer that had a large brightly lit display and a complete bus. The Zenith laptop screen was the only screen that was judged acceptable by a panel of low vision users.

A computer bus consists of power, control, and data, signals that enable the central processing unit (CPU) to communicate with memory and peripherals. AFI needed to design a Zenith bus interface to make the hand held optical scanner and the large print program work. We were unable to complete this task because we could not obtain adequate technical information on the Zenith 184 Super Sport bus. Zenith Corporation told us they are applying for a patent on their bus and were not able to give us detailed technical information at this time. The Zenith laptop computer display was the only screen adequate for use by low vision users. To complete the remaining objectives of this project we must obtain more information from Zenith or wait for another manufacturer to implement a suitable screen on a laptop computer. Recent activity in the laptop market indicates that other vendors will offer larger and brighter screens.

We are continuing the PACE research, at our own expense. AFI is confident that we will make PACE a reality. We will either get the system working on the Zenith laptop or another portable computer. The PACE system successfully implemented on the desk top computer is available for use by low vision computer users.

We thank the Department of Education for funding this research. We believe strongly in our work and although this project did not succeed in all objectives we have demonstrated that a PACE system is possible. PACE is an excellent concept and we are confident that it will serve as an aid to many low vision students and workers in the near future.

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